US009291974B2

(12) United States Patent
Sugiyama

(10) Patent No.: US 9,291,974 B2
(45) Date of Patent: Mar. 22, 2016

(54) IMAGE FORMING APPARATUS EXECUTING A PLURALITY OF TYPES OF MISREGISTRATION CORRECTION CONTROL

(71) Applicant: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(72) Inventor: **Yuki Sugiyama**, Numazu (JP)

(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/287,520**

(22) Filed: **May 27, 2014**

(65) **Prior Publication Data**

US 2014/0363211 A1 Dec. 11, 2014

(30) **Foreign Application Priority Data**

Jun. 6, 2013 (JP) 2013-120107

(51) **Int. Cl.**
G03G 15/20 (2006.01)
G03G 15/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/5058*** (2013.01); *G03G 2215/0132* (2013.01); *G03G 2215/0161* (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/6573; G03G 21/00; G03G 2215/00421; G03G 15/6502; B41J 2/335
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,571,451	B2 *	10/2013	Teshima et al.	399/301
8,600,274	B2	12/2013	Uchiyama et al.	
2006/0139433	A1 *	6/2006	Yoshida	347/116
2007/0122171	A1 *	5/2007	Fujimori et al.	399/38
2008/0279599	A1 *	11/2008	Nagatsuka	399/301
2012/0328310	A1 *	12/2012	Ohashi	399/39
2013/0100226	A1 *	4/2013	Ninomiya	347/224
2014/0016955	A1	1/2014	Uchiyama et al.	

FOREIGN PATENT DOCUMENTS

JP	2003-207976	A	7/2003
JP	2008-033168	A	2/2008
JP	2010-091925	A	4/2010
JP	2012-032777	A	2/2012

* cited by examiner

Primary Examiner — Clayton E Laballe
Assistant Examiner — Ruifeng Pu
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

An image forming apparatus includes: an image forming unit configured to form developer images of a plurality of colors on an image carrier; and a control unit configured to execute a first correction control and a second correction control that has a higher correction precision than the first correction control in order to correct misregistration between the developer images formed by the image forming unit. The control unit is further configured to execute the second correction control when a cumulative correction error, which is a cumulative value of correction error occurring when performing misregistration correction using the first correction control, exceeds a first threshold.

22 Claims, 12 Drawing Sheets

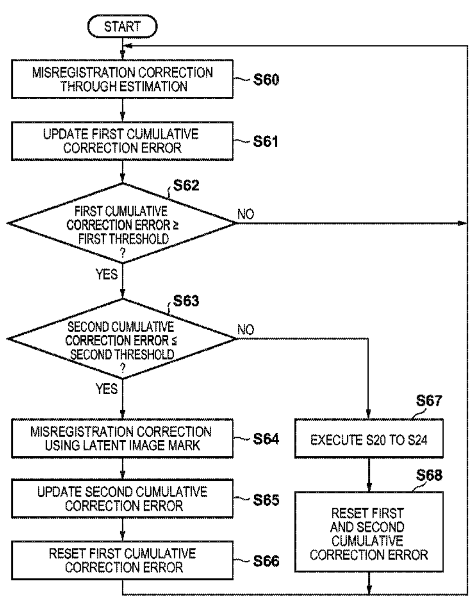
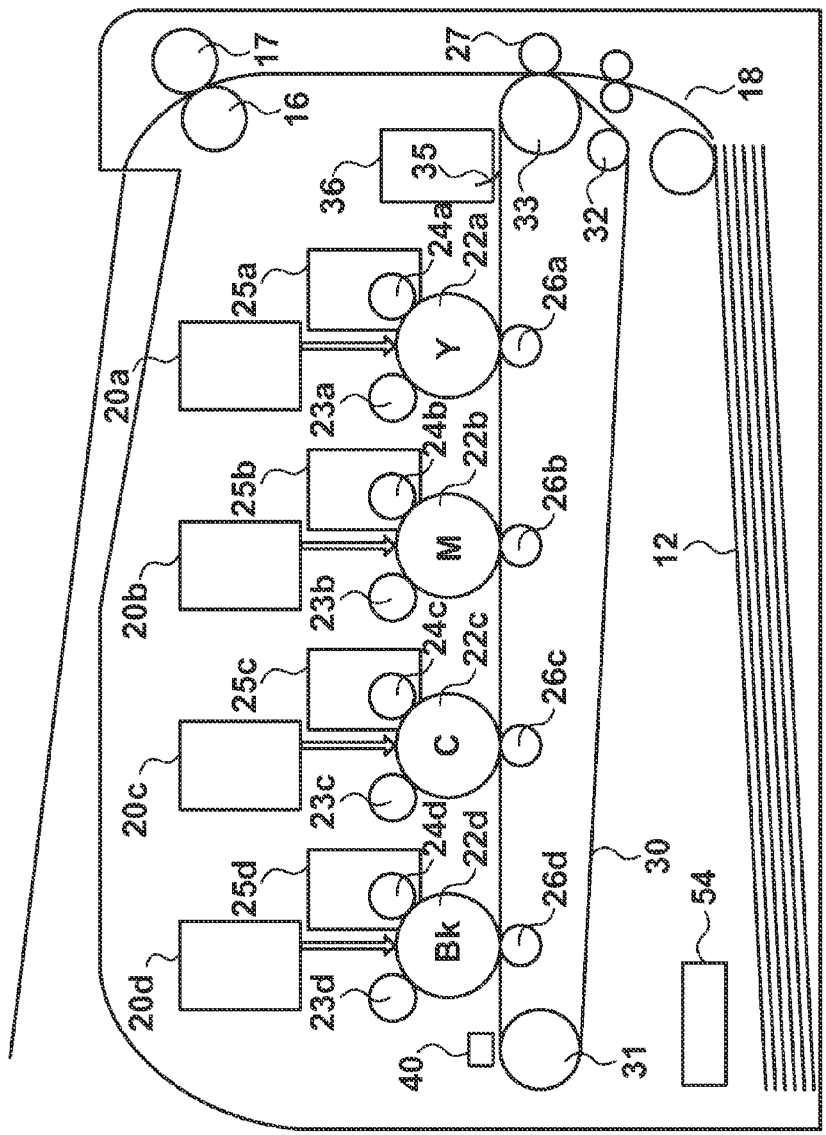


FIG. 1



12
16
17
18
20a
20b
20c
20d
22a
22b
22c
22d
23a
23b
23c
23d
24a
24b
24c
24d
25a
25b
25c
25d
26a
26b
26c
26d
27
30
31
32
33
35
36
40
54
Y
M
C
Bk

FIG. 2A

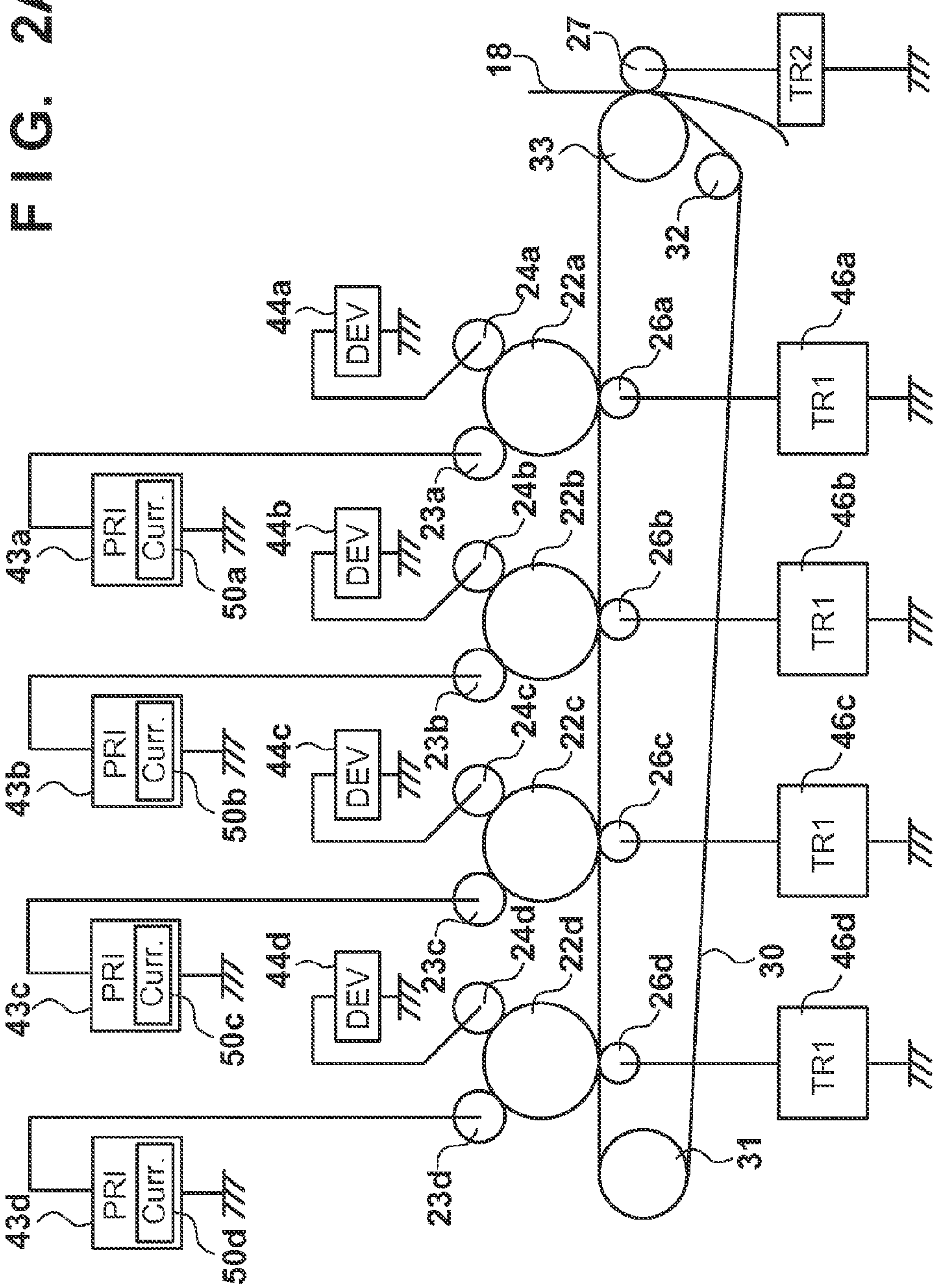

PRI
Curr.
DEV
TR1
TR2
43a
43b
43c
43d
50a
50b
50c
50d
44a
44b
44c
44d
23a
23b
23c
23d
24a
24b
24c
24d
22a
22b
22c
22d
26a
26b
26c
26d
46a
46b
46c
46d
18
27
33
32
30
31

FIG. 2B

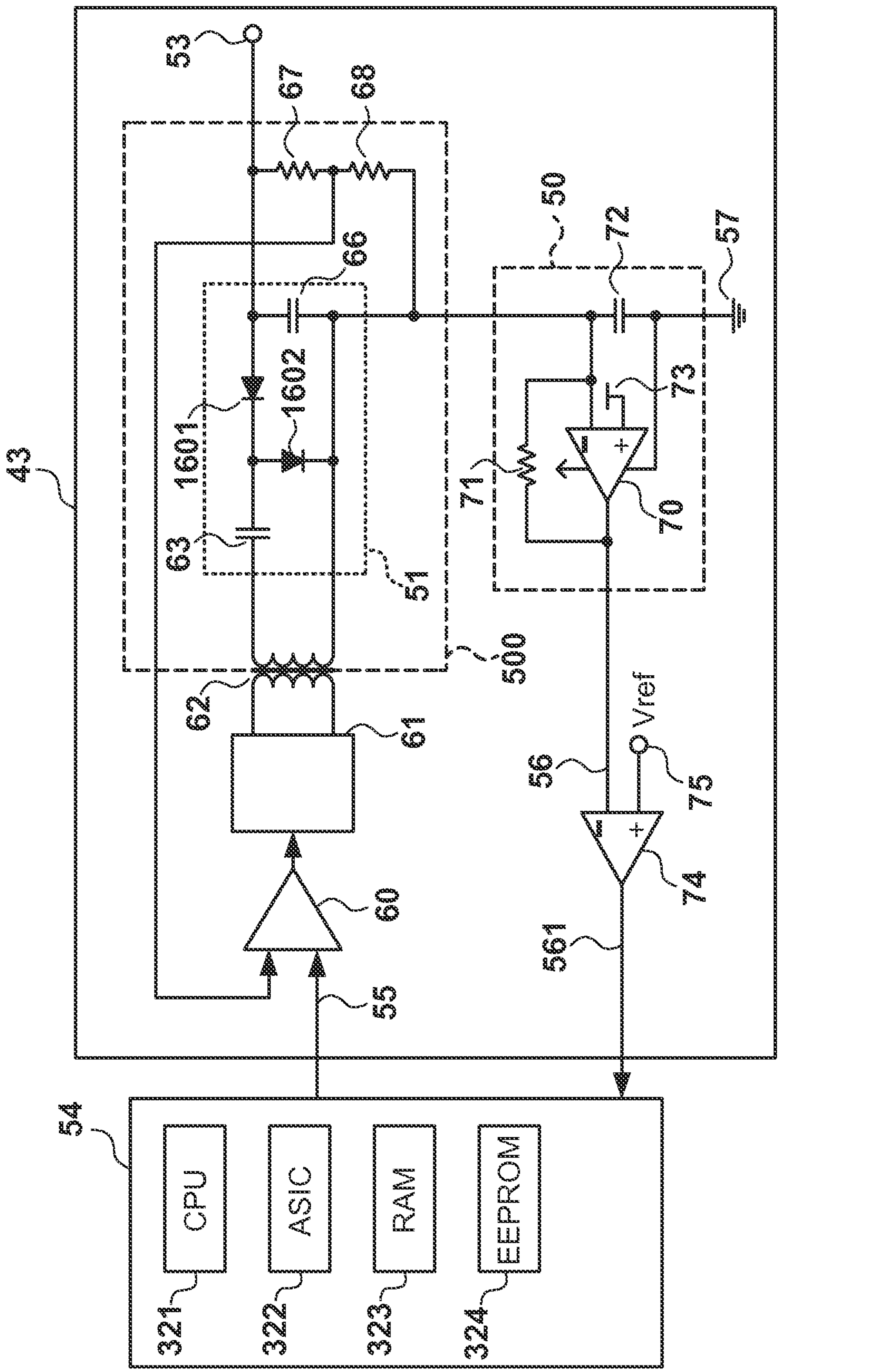

43
53
67
68
50
72
57
66
1601
1602
73
71
70
63
51
500
62
61
Vref
56
75
74
60
561
55
54
CPU
ASIC
RAM
EEPROM
321
322
323
324

FIG. 3

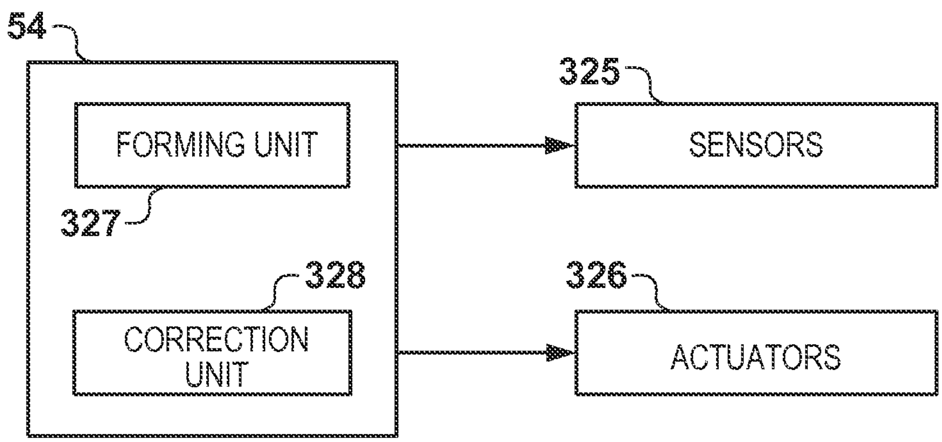

54
FORMING UNIT
327
328
CORRECTION UNIT
325
SENSORS
326
ACTUATORS

FIG. 4

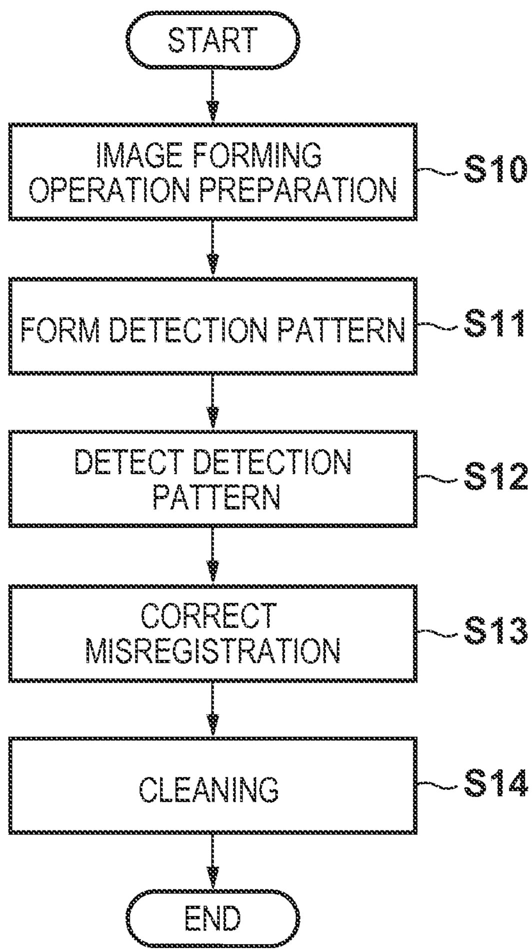

START
IMAGE FORMING OPERATION PREPARATION
S10
FORM DETECTION PATTERN
S11
DETECT DETECTION PATTERN
S12
CORRECT MISREGISTRATION
S13
CLEANING
S14
END

FIG. 5A

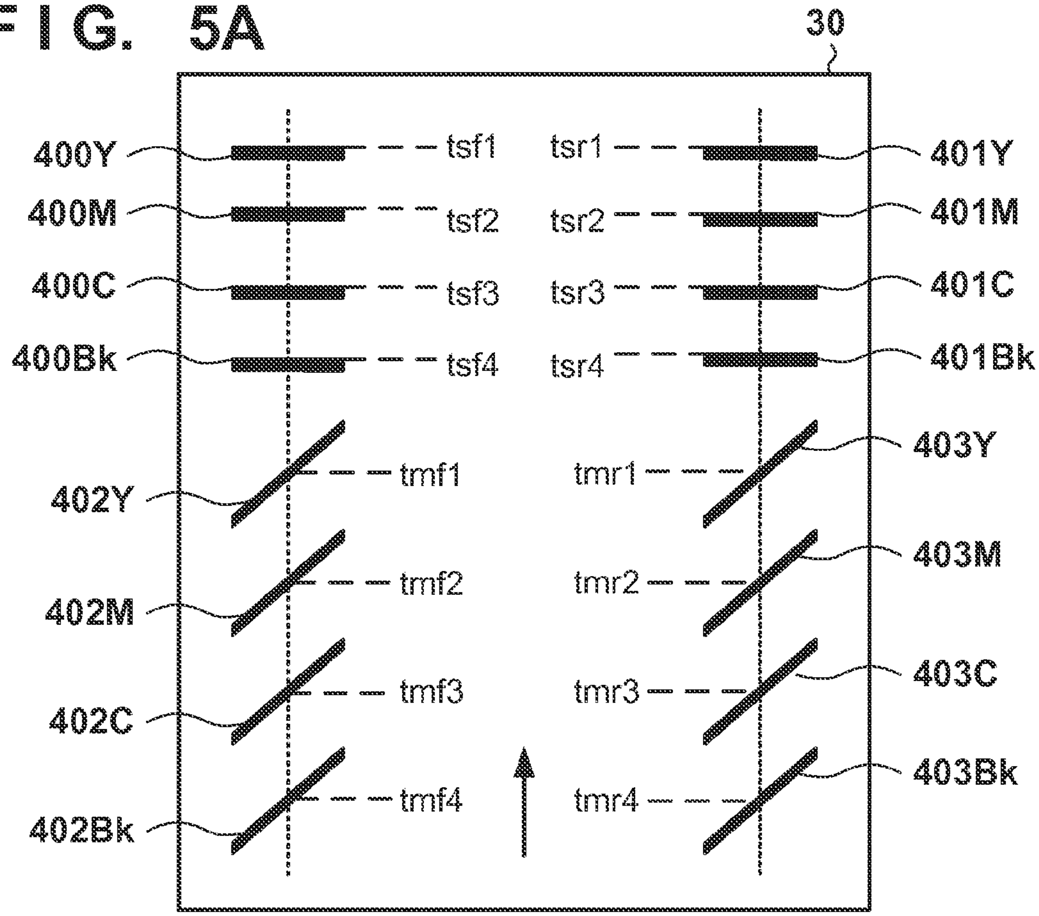

30
400Y
tsf1
tsr1
401Y
400M
tsf2
tsr2
401M
400C
tsf3
tsr3
401C
400Bk
tsf4
tsr4
401Bk
402Y
tmf1
tmr1
403Y
402M
tmf2
tmr2
403M
402C
tmf3
tmr3
403C
402Bk
tmf4
tmr4
403Bk

FIG. 5B

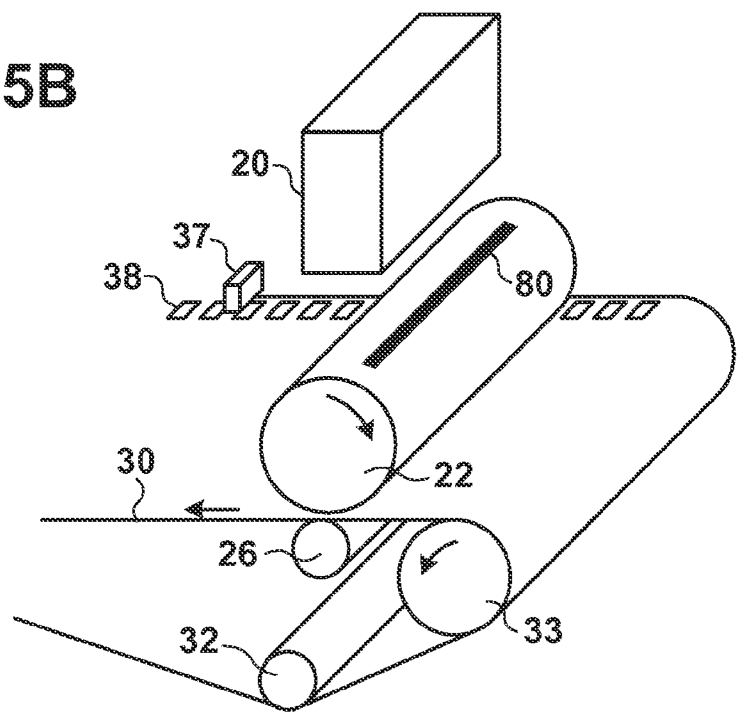

20
37
38
80
22
30
26
32
33

FIG. 6A

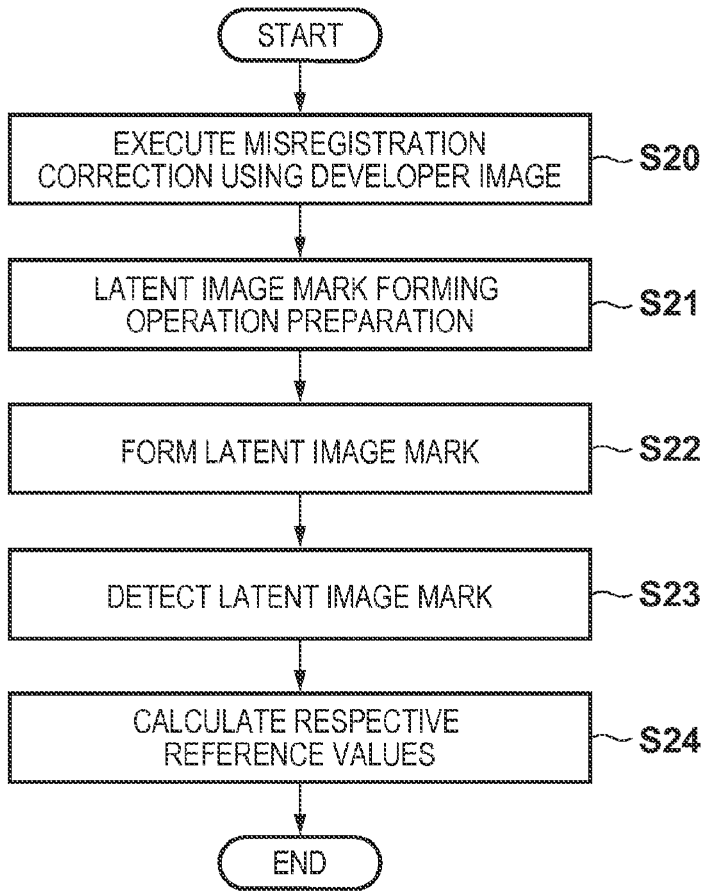

START
EXECUTE MISREGISTRATION CORRECTION USING DEVELOPER IMAGE
S20
LATENT IMAGE MARK FORMING OPERATION PREPARATION
S21
FORM LATENT IMAGE MARK
S22
DETECT LATENT IMAGE MARK
S23
CALCULATE RESPECTIVE REFERENCE VALUES
S24
END

FIG. 6B

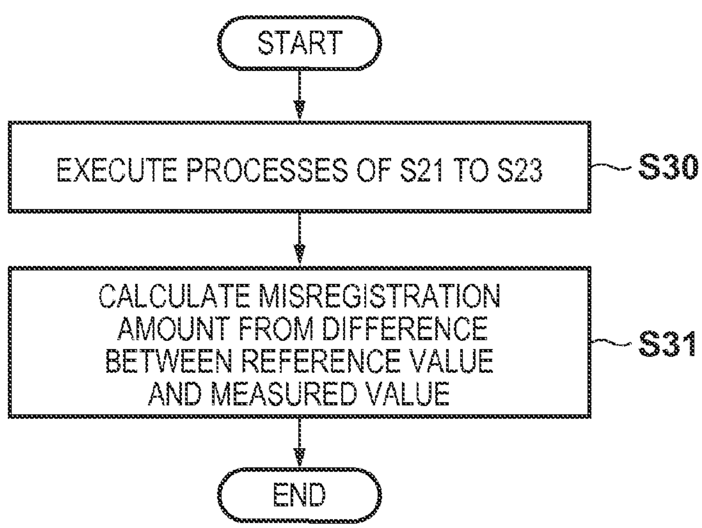

START
EXECUTE PROCESSES OF S21 TO S23
S30
CALCULATE MISREGISTRATION AMOUNT FROM DIFFERENCE BETWEEN REFERENCE VALUE AND MEASURED VALUE
S31
END

FIG. 7

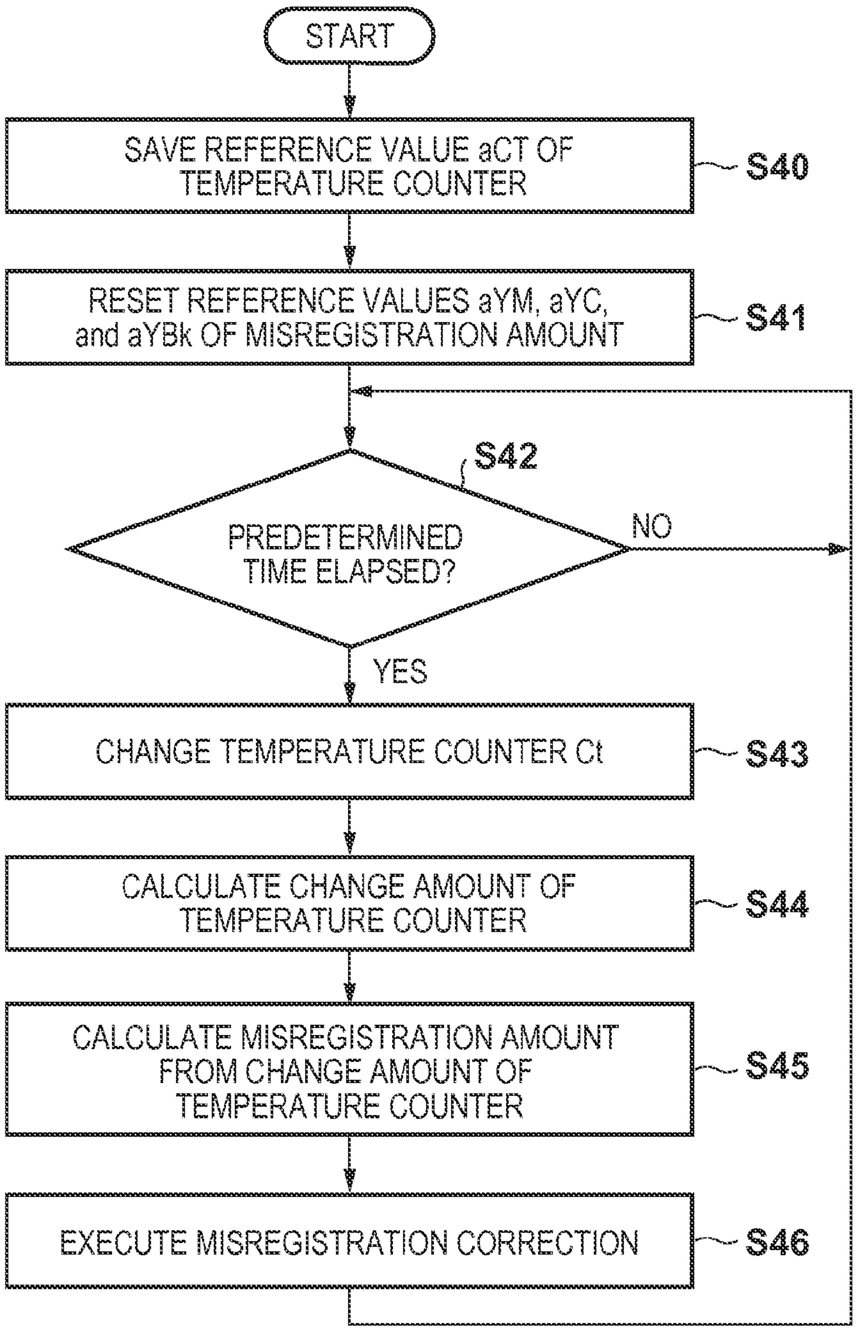

START
SAVE REFERENCE VALUE aCT OF TEMPERATURE COUNTER
S40
RESET REFERENCE VALUES aYM, aYC, and aYBk OF MISREGISTRATION AMOUNT
S41
S42
PREDETERMINED TIME ELAPSED?
NO
YES
CHANGE TEMPERATURE COUNTER Ct
S43
CALCULATE CHANGE AMOUNT OF TEMPERATURE COUNTER
S44
CALCULATE MISREGISTRATION AMOUNT FROM CHANGE AMOUNT OF TEMPERATURE COUNTER
S45
EXECUTE MISREGISTRATION CORRECTION
S46

FIG. 8A

	DURING PRINTING	NOT DURING PRINTING
Ct<100	+4	-1
100≤Ct<200	+3	-2
200≤Ct<300	+2	-3
300≤Ct	+1	-4

FIG. 8B

	ΔYM	ΔYC	ΔYBk
ΔCt<-400	-1	+2	+2
-400≤ΔCt<-200	0	+1	+1
-200≤ΔCt≤300	0	0	0
300<ΔCt≤500	0	-1	-1
500<ΔCt	+1	-2	-2

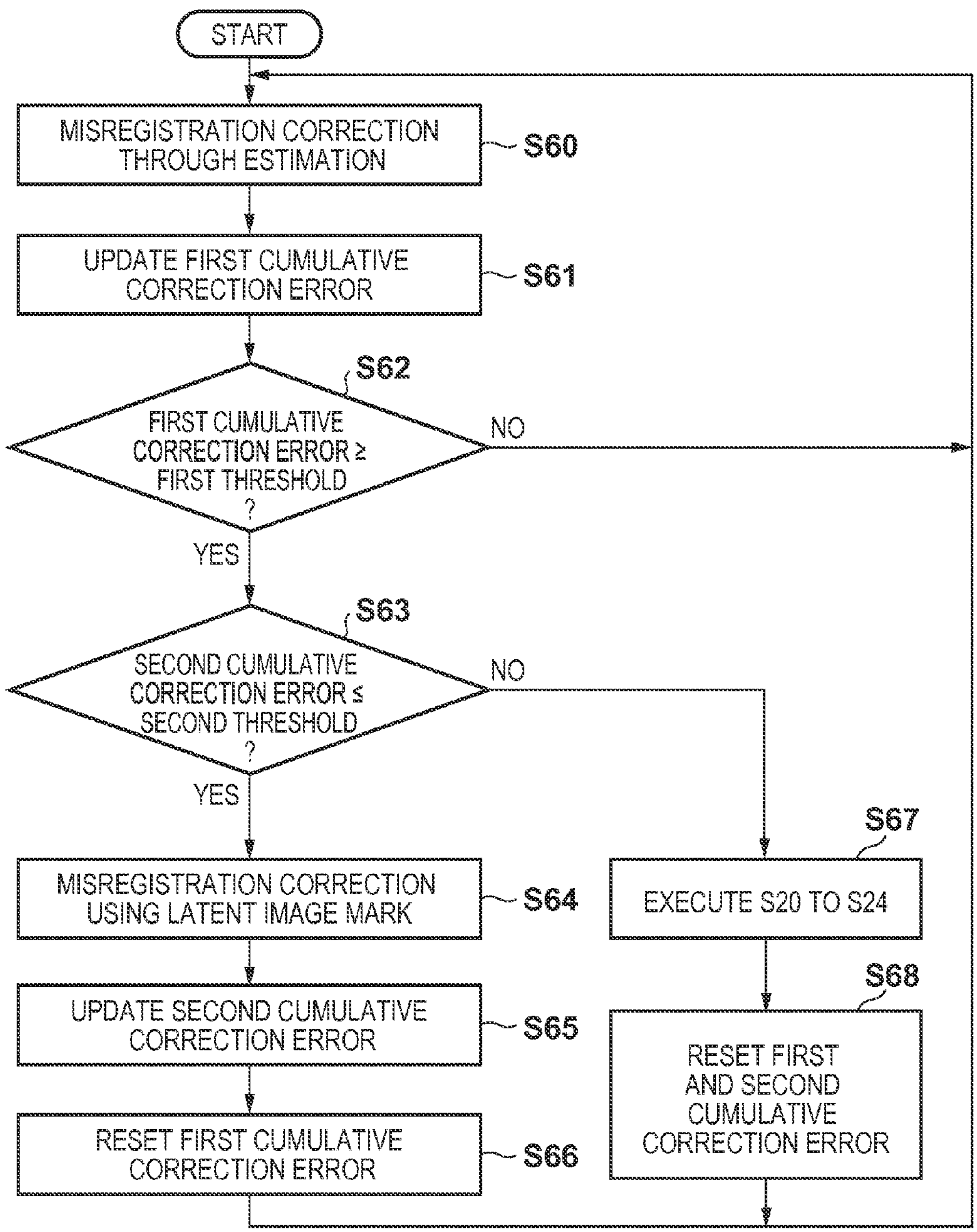
FIG. 9A

	MAGENTA	CYAN	BLACK
ΔCt<-400	+3	+6	+6
-400≤ΔCt<-200	+1	+3	+3
-200≤ΔCt≤300	0	0	0
300<ΔCt≤500	+1	+3	+3
500<ΔCt	+3	+6	+6

FIG. 9B

	YELLOW	MAGENTA	CYAN	BLACK
N≥102%	-3	-2	-1	-1
102%>N≥101%	-2	-1	0	0
101%>N≥99%	0	0	0	0
99%>N≥98%	+1	+2	+3	+3
98%>N	+2	+2	+3	+3

FIG. 10


START
MISREGISTRATION CORRECTION THROUGH ESTIMATION
S60
UPDATE FIRST CUMULATIVE CORRECTION ERROR
S61
S62
FIRST CUMULATIVE CORRECTION ERROR ≥ FIRST THRESHOLD ?
NO
YES
S63
SECOND CUMULATIVE CORRECTION ERROR ≤ SECOND THRESHOLD ?
NO
YES
MISREGISTRATION CORRECTION USING LATENT IMAGE MARK
S64
UPDATE SECOND CUMULATIVE CORRECTION ERROR
S65
RESET FIRST CUMULATIVE CORRECTION ERROR
S66
S67
EXECUTE S20 TO S24
S68
RESET FIRST AND SECOND CUMULATIVE CORRECTION ERROR

F I G. 11A

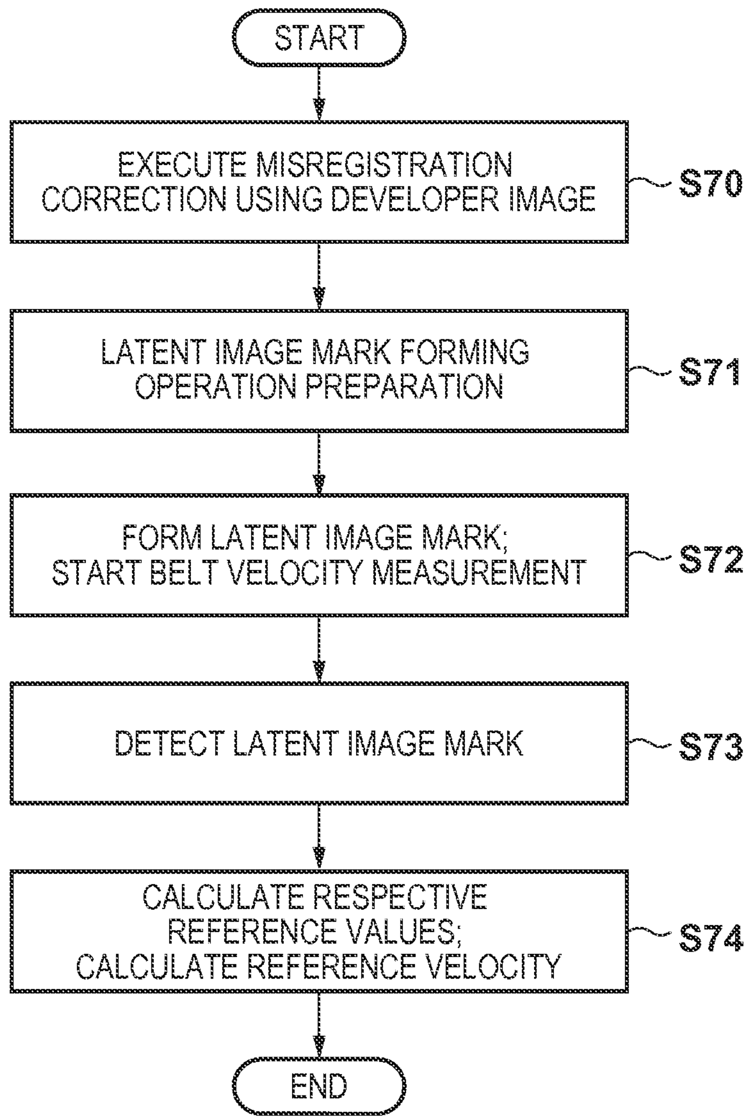

START
EXECUTE MISREGISTRATION CORRECTION USING DEVELOPER IMAGE
S70
LATENT IMAGE MARK FORMING OPERATION PREPARATION
S71
FORM LATENT IMAGE MARK; START BELT VELOCITY MEASUREMENT
S72
DETECT LATENT IMAGE MARK
S73
CALCULATE RESPECTIVE REFERENCE VALUES; CALCULATE REFERENCE VELOCITY
S74
END

FIG. 11B

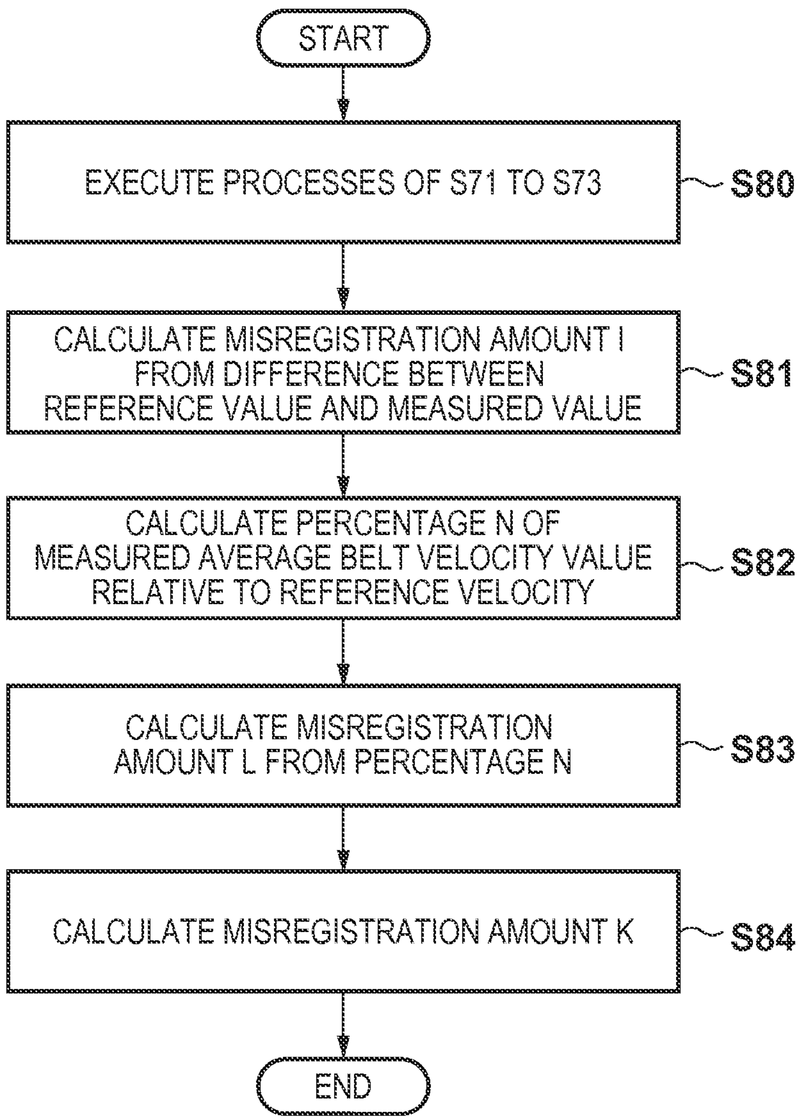

START
EXECUTE PROCESSES OF S71 TO S73
S80
CALCULATE MISREGISTRATION AMOUNT I FROM DIFFERENCE BETWEEN REFERENCE VALUE AND MEASURED VALUE
S81
CALCULATE PERCENTAGE N OF MEASURED AVERAGE BELT VELOCITY VALUE RELATIVE TO REFERENCE VELOCITY
S82
CALCULATE MISREGISTRATION AMOUNT L FROM PERCENTAGE N
S83
CALCULATE MISREGISTRATION AMOUNT K
S84
END

IMAGE FORMING APPARATUS EXECUTING A PLURALITY OF TYPES OF MISREGISTRATION CORRECTION CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to electrophotographic image forming apparatuses, and particularly relates to misregistration correction control in image forming apparatuses.

2. Description of the Related Art

A so-called "tandem" type image forming apparatus, in which image forming units are provided independently for each color in order to print at high speeds, is known as a type of electrophotographic image forming apparatus. Such tandem-type image forming apparatuses are configured so that images are sequentially transferred from each color image forming unit onto an intermediate transfer belt and the images are then transferred from the intermediate transfer belt onto a recording medium at one time. In such an image forming apparatus, color misregistration (misregistration) can arise when superimposing the images due to mechanical factors in each color image forming unit. The image forming apparatus therefore carries out misregistration correction in order to form high-quality images.

Misregistration occurs when the positions, shapes, and so on of components involved in image formation change due to changes in temperature in the image forming apparatus resulting from continuous printing. It is thus necessary to execute misregistration correction periodically, even when continuous printing is underway. However, a user cannot print while the misregistration correction is underway, resulting in downtime for the user. Accordingly, there is demand for an image forming apparatus that improves the usability by reducing such downtime.

Japanese Patent Laid-Open No. 2012-032777 discloses a configuration that corrects misregistration by detecting an electrostatic latent image for correction formed on a photosensitive member in order to reduce downtime.

However, although the configuration disclosed in Japanese Patent Laid-Open No. 2012-032777 can correct misregistration originating on the photosensitive member, the configuration cannot correct misregistration originating on an intermediate transfer belt.

SUMMARY OF THE INVENTION

According to an aspect of the present invention, an image forming apparatus comprising: an image forming unit configured to form developer images of a plurality of colors on an image carrier; and a control unit configured to execute a first correction control and a second correction control that has a higher correction precision than the first correction control in order to correct misregistration between the developer images formed by the image forming unit. The control unit is further configured to execute the second correction control when a cumulative correction error, which is a cumulative value of correction error occurring when performing misregistration correction using the first correction control, exceeds a first threshold.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating an overview of an image forming apparatus according to an embodiment.

FIGS. **2**A and **2**B are diagrams illustrating a system for supplying a voltage to an image forming apparatus according to an embodiment.

FIG. **3** is a diagram illustrating a control configuration in an image forming apparatus according to an embodiment.

FIG. **4** is a flowchart illustrating an example of misregistration correction using an electrostatic latent image.

FIG. **5**A is a diagram illustrating a detection pattern according to an embodiment.

FIG. **5**B is a diagram illustrating a latent image mark according to an embodiment.

FIGS. **6**A and **6**B are flowcharts illustrating an example of misregistration correction using a latent image mark.

FIG. **7** is a flowchart illustrating an example of misregistration correction through estimation.

FIGS. **8**A and **8**B are diagrams illustrating examples of tables used by an image forming apparatus for misregistration correction.

FIGS. **9**A and **9**B are diagrams illustrating examples of tables used by an image forming apparatus for misregistration correction.

FIG. **10** is a flowchart illustrating an overall misregistration correction process according to an embodiment.

FIGS. **11**A and **11**B are flowcharts illustrating an example of misregistration correction using a latent image mark.

DESCRIPTION OF THE EMBODIMENTS

Hereinafter, exemplary embodiments of the present invention will be described with reference to the drawings. Note that constituent elements not necessary for the descriptions of embodiments have been omitted from the drawings. Note also that the following embodiments are to be taken as examples only, and are not intended to limit the scope of the present invention.

First Embodiment

In the present embodiment, the following three types of misregistration correction control are executed selectively:

First correction control: misregistration correction through estimation.

Second correction control: misregistration correction using an electrostatic latent image.

Third correction control: misregistration correction using a developer image.

FIG. **1** is a schematic diagram illustrating an overview of an image forming apparatus according to the present embodiment. Note that the letters a, b, c, and d appended to reference numerals indicate that the color of a developer image whose formation the corresponding member is involved with is yellow (Y), magenta (M), cyan (C), or black (Bk), respectively. Note also that the appended letters a, b, c, and d will be left off the reference numerals in the following descriptions in cases where it is not necessary to distinguish between individual colors. A photosensitive member **22** is an image carrier, and is rotationally driven. A charging roller **23** charges a surface of a corresponding photosensitive member **22** to a uniform potential. For example, a charging bias output by the charging roller **23** is −1200 V, and as a result, the surface of the photosensitive member **22** is charged to a potential (a dark potential) of −700 V. A scanner unit **20** forms an electrostatic latent image on the photosensitive member **22** by scanning the surface of the photosensitive member **22** with a laser beam based on image data expressing an image to be formed. For example, the laser beam scanning results in a potential (a light potential) of −100 V in the areas where the electrostatic latent image is formed. A developing unit **25** holds developer of a corresponding color, and develops the electrostatic latent image on the photosensitive member **22** by supplying the developer to the electrostatic latent image on the photosensitive member **22** using a developing sleeve **24**. For example, a developing bias output by the developing sleeve **24** is −350 V, and the developing unit **25** causes the developer to adhere to the electrostatic latent image using this potential. A primary transfer roller **26** transfers the developer image on the photosensitive member **22** onto an intermediate transfer belt **30** that is an image carrier and is cyclically driven using rollers **31**, **32**, and **33**. For example, a transfer bias output by the primary transfer roller **26** is +1000 V, and the primary transfer roller **26** transfers the developer onto the intermediate transfer belt **30** using this potential. Note that at this time, the developer image on each photosensitive member **22** is transferred onto the intermediate transfer belt **30** so as to overlap, thus forming a color image.

A secondary transfer roller **27** transfers the developer image on the intermediate transfer belt **30** onto a recording medium **12** transported along a transport path **18**. A fixing roller pair **16** and **17** thermally fixes the developer image transferred onto the recording medium **12**. A cleaning blade **35** collects developer not transferred from the intermediate transfer belt **30** onto the recording medium **12** by the secondary transfer roller **27** into a receptacle **36**. In addition, a detection sensor **40** is provided facing the intermediate transfer belt **30** in order to correct misregistration by forming the developer image. Note that a control unit **54** controls the image forming apparatus as a whole.

Note that the scanner unit **20** can also scan the photosensitive member **22** using an LED array or the like rather than a laser. Furthermore, rather than employing the intermediate transfer belt **30**, the image forming apparatus may be a direct-transfer type that directly transfers the developer image from each photosensitive member **22** onto the recording medium **12**.

FIG. **2**A illustrates a configuration for supplying power to the image forming apparatus. A charging power source circuit **43** supplies, to the charging roller **23**, the charging bias through which the corresponding charging roller **23** charges the surface of the photosensitive member **22**. Likewise, a developing power source circuit **44** supplies the developing bias to the corresponding developing sleeve **24**, and a primary transfer power source circuit **46** supplies a primary transfer bias to the corresponding primary transfer roller **26**. Note that in the present embodiment, the charging power source circuit **43** includes a current detection circuit **50**.

FIG. **2**B illustrates a circuit configuration of the charging power source circuit **43** shown in FIG. **2**A. A transformer **62** boosts the voltage of an AC signal generated by a driving circuit **61** to an amplitude several tens of times thereof. A rectifier circuit **51** including diodes **1601** and **1602** and capacitors **63** and **66** rectifies and smoothes the boosted AC voltage. The rectified and smoothed voltage is then output from an output terminal **53** as a negative DC voltage. A comparator **60** controls the output voltage of the driving circuit **61** so that the voltage of the output terminal **53** divided by detection resistances **67** and **68** equals a voltage setting value **55** set by the control unit **54**. Note that a current flows through the photosensitive member **22**, the charging roller **23**, and to a ground in accordance with the voltage at the output terminal **53**. This current is referred to as a "charging current" hereinafter.

The current detection circuit **50** is inserted between a secondary side circuit **500** of the transformer **62** and a ground **57**. An input terminal of an operational amplifier **70** has a high impedance and almost no current flows therein, and thus almost all of the charging current flows to a resistance **71**. Meanwhile, the potential at an inverted input terminal of the operational amplifier **70** is approximately equal to a reference voltage **73** connected to a non-inverted input terminal. Accordingly, a detection voltage **56** corresponding to the charging current appears at an output terminal of the op operational amplifier **70**. Specifically, the detection voltage **56** decreases as the charging current rises and the detection voltage **56** increases as the charging current drops. Note that a capacitor **72** is provided to stabilize the inverted input terminal of the operational amplifier **70**.

The detection voltage **56** corresponding to the charging current is input to a negative terminal of a comparator **74**. A reference voltage (Vref) **75** serving as a threshold is input to a positive terminal of the comparator **74**, and a binary voltage **561** based on a magnitude relationship between the detection voltage **56** and the reference voltage **75** serving as the threshold is input to the control unit **54**. Specifically, the comparator **74** outputs a high-level signal when the detection voltage **56** is lower than the reference voltage **75**, and outputs a low-level signal when such is not the case.

As described above, in the present embodiment, an electrostatic latent image for correction (hereinafter referred to as a "latent image mark") is used in the second correction control. Also as described above, the potential (light potential) of the surface of the photosensitive member **22** corresponding to the latent image mark is −100 V, for example, whereas the potential (dark potential) of the other parts of the surface of the photosensitive member **22** is −700 V, for example. Furthermore, as described above, the potential of the charging roller **23** is −1200 V, for example. Because the value of the charging current is determined by a potential difference between the surface of the photosensitive member **22** and the charging roller **23**, the charging current is greater while the latent image mark is passing a position that faces the charging roller **23** than when passing other positions. Accordingly, the detection voltage **56** is lower while the latent image mark is passing the position that faces the charging roller **23** than when passing other positions. The reference voltage **75** is set to a value that is between a minimum value of the detection voltage **56** during the stated passage and a value of the detection voltage **56** prior to the stated passage so that the latent image mark passing the position opposite to the charging roller **23** can be detected. Accordingly, when a single latent image mark passes the position opposite to the charging roller **23**, the comparator **74** outputs the binary voltage **561** having a single rise and a single fall. The control unit **54** employs, for example, a midpoint between the rise and fall of the binary voltage **561** as a detection position of the latent image mark. Note, however, that one of the rise and fall of the binary voltage **561** can also be employed as the detection position of the latent image mark.

The control unit **54** shown in FIG. **2**B carries out overall control of the operations of the image forming apparatus illustrated in FIG. **1**. Specifically, a CPU **321** of the control unit **54** uses a RAM **323** as a main memory and a work area, and controls the operations of the image forming apparatus described above in accordance with various types of control programs stored in an EEPROM **324**. Meanwhile, an ASIC **322** controls various motors, controls a high-voltage power source for the developing bias, and so on during various types of printing sequences, based on instructions from the CPU **321**. Note that some or all of the functions of the CPU **321** may be realized by the ASIC **322**, and conversely, some or all of the functions of the ASIC **322** may be realized instead by the CPU **321**. Furthermore, some of the functions of the control unit **54** may be offloaded onto hardware corresponding to another control unit **54**.

FIG. **3** is a functional block diagram illustrating a control configuration of the control unit **54**. "Sensors **325**" is a general term indicating types of sensors such as the current detection circuit **50**, the detection sensor **40**, and so on. "Actuators **326**" is a general term indicating types of actuators such as a driving motor for the photosensitive member **22**, separating motors that cause the developing unit **25** and the photosensitive member **22** to come into contact with/separate from each other, and so on. The control unit **54** performs various types of processes based on information obtained from the various types of sensors **325**. For example, a forming unit **327** forms the latent image mark, a developer image for misregistration correction, and so on in the second correction control, the third correction control, and so on. Meanwhile, a correction unit **328** selects and executes one of the aforementioned first correction control to third correction control.

Hereinafter, the three types of misregistration correction control according to the present embodiment will be described.

Misregistration Correction Using a Developer Image (Third Correction Control)

FIG. **4** is a flowchart illustrating misregistration correction using a developer image. In S**10**, the control unit **54** performs preparatory operations for image formation, and in S**11**, the control unit **54** forms, on the intermediate transfer belt **30**, a detection pattern including marks **400**, **401**, **402**, and **403** using developer, as shown in FIG. **5**A. In FIG. **5**A, the marks **400** and **401** form a pattern for detecting a misregistration amount in a moving direction of the intermediate transfer belt **30** (a sub scanning direction). Meanwhile, the marks **402** and **403** form a pattern for detecting a misregistration amount in a main scanning direction, which is orthogonal to the moving direction of the intermediate transfer belt **30**. Note that an arrow in FIG. **5**A corresponds to the moving direction of the intermediate transfer belt **30**, that is, the sub scanning direction. In the example shown in FIG. **5**A, the marks **402** and **403** are slanted 45 degrees relative to the main scanning direction. Note that the letters Y, M, C, and Bk appended to the reference numerals of the marks **400** to **403** indicate that the corresponding mark is formed from yellow, magenta, cyan, or black developer. Furthermore, each dotted line that passes through the marks in FIG. **5**A indicates the detection position of the detection sensor **40**.

In S**12**, the control unit **54** detects the marks in the detection pattern using the detection sensor **40**. tsfl-4, tmfl-4, tsrl-4, and tmrl-4 for the respective marks in FIG. **5**A indicate detection times at which the detection sensor **40** has detected the corresponding mark. Note that a known technique can be employed to detect the marks using the detection sensor **40**, such as using reflected light produced by irradiating the detection pattern with light. In S**13**, the control unit **54** obtains misregistration amounts in the sub scanning direction and the main scanning direction based on the detection time of each mark in FIG. **5**A, and corrects misregistration. Note that the method for calculating the misregistration amount is a known technique and thus detailed descriptions thereof will be omitted. To describe briefly, the control unit **54** determines a distance between marks based on a moving velocity of the intermediate transfer belt **30** and a time difference between the detection times of the marks, and then calculates the misregistration amount based on the theoretical distance between the marks. Note also that the misregistration amount in the main scanning direction can be obtained from the marks **402** and **403** because when the marks **402** and **403** shift in the main scanning direction, the distance from the marks **400** and **401** at the detection position of the detection sensor **40** changes. In S**14**, the control unit **54** removes the detection pattern and cleans the intermediate transfer belt **30**.

In the misregistration correction control that uses the developer image, the detection pattern is formed on the intermediate transfer belt **30**, and the misregistration amount calculation is first carried out when the detection pattern reaches the detection region of the detection sensor **40**. Accordingly, this misregistration correction requires the greatest amount of time of the three types of misregistration correction control used in the present embodiment. However, this misregistration correction control can calculate the misregistration amount having taken into account all of the factors that cause misregistration, including variations in the illumination position of the scanner unit **20**, variations in the rotational velocity of the photosensitive member **22**, and variations in the movement velocity of the surface of the intermediate transfer belt **30**, and therefore offers the best misregistration correction. Furthermore, in the misregistration correction control that uses a developer image, the misregistration amount in the main scanning direction can be detected as well as the misregistration amount in the sub scanning direction.

Misregistration Correction Using a Latent Image Mark (Second Correction Control)

Next, the misregistration correction using a latent image mark will be described using FIGS. **6**A and **6**B. The misregistration correction using a latent image mark includes two processes, namely a process for obtaining a reference value and a process for correcting misregistration based on the reference value. FIG. **6**A is a flowchart illustrating the process for obtaining the reference value.

In S**20**, the control unit **54** executes the process illustrated in FIG. **4**. Doing so results in a minimum amount of misregistration. Then, in S**21**, the control unit **54** performs preparatory operations for forming the latent image mark, and in S**22**, forms one or more latent image marks on the photosensitive member **22**. FIG. **5**B illustrates a state in which a latent image mark **80** has been formed on the photosensitive member **22**. Note that a detection sensor **37** and belt velocity detection marks **38** illustrated in FIG. **5**B are not used in the present embodiment. In S**23**, the control unit **54** detects the latent image mark based on the charging current. In S**24**, the control unit **54** saves the amount of time until the latent image mark **80** formed in S**22** is detected in S**23** as the reference value. Note that in the case where a plurality of latent image marks **80** are formed, an average value of the times until each latent image mark **80** that has been formed is detected can be used as the reference value. Note that this process is executed for each photosensitive member **22**.

Next, misregistration correction using the reference value obtained through the process illustrated in FIG. **6**A will be described using FIG. **6**B. In S**30**, the control unit **54** executes the processes of S**21** to S**23** of FIG. **6**A, and measures the amount of time from the formation to detection of the latent image mark **80**, for each photosensitive member **22**. Then, in S**31**, the control unit **54** carries out correction using a difference between the measured time and the reference value as the misregistration amount. In other words, the control unit **54** carries out the correction so that the time from the formation to detection of the latent image mark **80** matches the reference value.

In the misregistration correction using the latent image mark **80**, the misregistration amount detection can be started by the latent image mark **80** reaching a position that faces the charging roller **23**, and thus can be carried out in a shorter amount of time than the misregistration correction using a developer image. However, this correction cannot detect misregistration caused by the intermediate transfer belt **30**, such as variations in the movement velocity of the surface of the intermediate transfer belt **30**, and thus the misregistration amount is less precise than when using a developer image.

Misregistration Correction Through Estimation (First Correction Control)

The misregistration correction through estimation will be described using the flowchart in FIG. **7**. The misregistration correction through estimation employs a temperature counter Ct. The temperature counter Ct simulates a temperature within the apparatus. Note that when the image forming apparatus is turned on, the temperature counter Ct is reset to 0. When the misregistration correction through estimation starts, in S**40**, the control unit **54** saves the temperature counter at that point in time as a reference value aCT. In S**41**, the control unit **54** resets misregistration amounts aYM, aYC, and aYBk occurring at that point in time. Here, the misregistration amounts aYM, aYC, and aYBk indicate misregistration amounts of magenta, cyan, and black relative to yellow in terms of numbers of lines. For example, in the case where the control unit **54** recognizes the misregistration amount at that point in time, the misregistration amount is reset to that misregistration amount. On the other hand, in the case where the control unit **54** does not recognize the misregistration amount at that time, the misregistration amount is reset to a predetermined value, such as 0. In S**42**, the control unit **54** waits until a predetermined amount of time has passed, and in S**43**, changes the temperature counter Ct. Note that the value to which the temperature counter Ct is changed follows the table shown in FIG. **8**A, which is saved in the image forming apparatus in advance. Note also that FIG. **8**A is merely an example. In S**44**, the control unit **54** calculates a change amount ΔCt of the current temperature counter Ct from the reference value aCT, through the formula Ct-aCT. In S**45**, the control unit **54** determines respective misregistration amounts ΔYM, ΔYC, and ΔYBk based on the change amount ΔCt in the temperature counter and a table shown in FIG. **8**B that is saved in the image forming apparatus in advance. Note that the table shown in FIG. **8**B is merely an example, and indicates misregistration amounts in terms of numbers of lines. In S**46**, the control unit **54** corrects the misregistration amount found in S**45**, and repeats the process from S**42**.

In the present embodiment, values obtained by averaging the variation properties of misregistration amounts measured for a plurality of individual image forming apparatuses of the same model are used as the values in the table shown in FIG. **8**B. Unlike the other two types of misregistration correction, the misregistration correction through estimation produces no downtime. However, because the correction uses estimated values based on average properties of the image forming apparatus rather than actually-measured values, the precision of the misregistration correction is the lowest of the three types.

Note that the misregistration correction can employ any desired method, such as adjusting the illumination timing of the scanner unit **20**, correcting the rotational velocity of the photosensitive member **22**, mechanically adjusting the position of a reflecting mirror provided in the scanner unit **20**, and so on.

Next, detection error in each type of misregistration correction will be described. Because detection error results in misregistration correction error, detection error will be called “correction error” hereinafter.

Correction Error in Misregistration Correction Through Estimation

In the misregistration correction through estimation, a difference between the misregistration amount in the image forming apparatus in question and an average value of misregistration amounts in a plurality of image forming apparatuses used to create the tables in FIGS. **8**A and **8**B corresponds to the correction error. Accordingly, the value of a difference between a maximum value of variation between the misregistration amounts in the plurality of image forming apparatuses and the average misregistration amount is used as the correction error. FIG. **9**A illustrates correction error when the misregistration correction through estimation has been executed once. Each time the misregistration correction through estimation is executed, the control unit **54** integrates the values in FIG. **9**A and saves the result as a cumulative correction error (first cumulative correction error) for the misregistration correction through estimation. Note that the table in FIG. **9**A indicates the misregistration amounts in terms of a number of lines.

Correction Error in Misregistration Correction Using a Latent Image Mark

Because the misregistration correction using a latent image mark detects the misregistration amount resulting from a several factors out of a plurality of factors that cause misregistration, misregistration amounts resulting from other factors corresponds to the correction error. In the present embodiment, the value of a difference between the misregistration amount in the misregistration correction using a latent image mark and the misregistration amount in the case where the misregistration correction through estimation has been executed is employed as the correction error for the misregistration correction using a latent image mark. Accordingly, each time the misregistration correction using a latent image mark is executed, the control unit **54** integrates the correction error and takes the result of the integration as a cumulative correction error (second cumulative correction error) for the misregistration correction using a latent image mark.

Correction Error in Misregistration Correction Using a Developer Image

In the present embodiment, the correction error for the misregistration correction using a developer image is assumed to be 0. Note that when the misregistration correction using a developer image is executed, the cumulative correction error of the misregistration correction through estimation and the misregistration correction using a latent image mark are reset to their initial values, or in other words, to 0.

Misregistration Correction According to the Present Embodiment

The overall misregistration correction according to the present embodiment will be described next. Note that when the apparatus is turned on, the process illustrated in FIG. **6**A is carried out, and a reference value for misregistration correction using a latent image mark is obtained. Furthermore, the error in the misregistration correction through estimation, or in other words, the first cumulative correction error, and the error in the misregistration correction using a latent image mark, or in other words, the second cumulative correction error, are reset to their initial values of 0.

FIG. **10** is a flowchart illustrating a process executed by the control unit **54** after the process performed when the power is turned on has been executed. In S**60**, the control unit **54** executes the misregistration correction through estimation illustrated in FIG. **7**, and in S**61**, updates the first cumulative correction error. Then, in S**62**, the control unit **54** determines whether the first cumulative correction error has become greater than or equal to a predetermined first threshold. If the first cumulative correction error is less than the first threshold, the process of **S60** is repeated at the timing of the next misregistration correction.

On the other hand, when the first cumulative correction error becomes greater than or equal to the first threshold, in **S63**, the control unit **54** determines whether the second cumulative correction error is less than or equal to a second threshold. If the second cumulative correction error is less than or equal to the second threshold, the control unit **54** executes the misregistration correction using a latent image mark described with reference to FIG. **6**B at the timing of the next misregistration correction indicated in **S64**, and updates the second cumulative correction error in **S65**. Thereafter, in **S66**, the control unit **54** sets the first cumulative correction error to an initial value of 0 and returns to **S60**. Note that it is not absolutely necessary to set the first cumulative correction error to the initial value of 0, and for example, the first cumulative correction error may be set to the initial value of 0 along with the second cumulative correction error in **S68**, which will be mentioned later.

On the other hand, in **S63**, when the second cumulative correction error is greater than the second threshold, the control unit **54** carries out the misregistration correction using a developer image and the process for obtaining the reference value for the misregistration correction using a latent image mark at the timing of the next misregistration correction, as indicated in **S67**. In other words, the processes of **S20** to **S24** shown in FIG. **6**A are executed. Thereafter, in **S68**, the control unit **54** sets the first cumulative correction error and the second cumulative correction error to an initial value of 0 and returns to **S60**. Note that the misregistration correction using a latent image mark performed thereafter uses the newest reference value obtained in **S67**. The control unit **54** executes the misregistration correction by repeating the process illustrated in FIG. **10** until the power is turned off.

According to the present embodiment, the misregistration correction through estimation, which has a low correction precision but does not produce downtime, is executed, and the first cumulative correction error occurring during the misregistration correction through estimation is monitored. When the first cumulative correction error exceeds a permissible range, the misregistration correction using a latent image mark, which produces downtime but has a higher correction precision, is executed; the second cumulative correction error is updated, and the first cumulative correction error is set to 0. Thereafter, when the first cumulative correction error and the second cumulative correction error both exceed their respective permissible ranges, the misregistration correction using a developer image, which produces a long downtime but offers the highest correction precision, is executed. In other words, the control unit **54** increases the frequency of execution of types of misregistration correction control that have lower correction precisions but produce less downtime. This configuration makes it possible to reduce downtime while maintaining a high level of precision in the misregistration correction.

In the present embodiment, three types of misregistration correction control offering different levels of correction precision are executed selectively. However, two types of misregistration correction control offering different levels of correction precision, such as misregistration correction through estimation and misregistration correction using a developer image, misregistration correction using a latent image mark and misregistration correction using a developer image, and so on, may be executed selectively. In this case, the control unit **54** carries out control so that the correction offering a lower level of precision is executed more frequently than the correction offering a high level of precision. In other words, the control unit **54** executes the misregistration correction offering a lower level of precision and monitors the cumulative correction error thereof; when the cumulative correction error exceeds a permissible range, the control unit **54** executes the misregistration correction offering a higher level of precision, and sets the cumulative correction error of the misregistration correction offering a lower level of precision to 0.

In addition, in the present embodiment, the latent image mark is detected based on the charging current flowing between the photosensitive member **22** and the charging roller **23**. However, the latent image mark can be detected based on a developing current or a transfer current flowing between the developing sleeve **24** or the primary transfer roller **26** that applies a voltage to the photosensitive member **22** and the photosensitive member **22**, and the like. Accordingly, the current detection circuit **50** may be provided in the developing power source circuit **44**, the primary transfer power source circuit **46**, or the like instead of in the charging power source circuit **43**, and may detect the latent image mark based on the developing current, the transfer current, or the like. Furthermore, in the case where, for example, constant current control that controls the transfer current to a constant value is employed, changes in the surface potential of the photosensitive member **22** are detected as changes in the voltage output by the primary transfer power source circuit **46**. In other words, a configuration in which the latent image mark **80** is detected based on an output voltage in addition to the currents output to the charging roller **23**, the developing sleeve **24**, and the primary transfer roller **26** from the power source circuit can be employed as well.

Furthermore, in the present embodiment, the cumulative correction error is obtained using the value of the difference between the misregistration amount in the misregistration correction through estimation and the misregistration amount in the misregistration correction using a latent image mark as the correction error in the misregistration correction using a latent image mark. However, for example, a value obtained by multiplying the cumulative correction error in the misregistration correction through estimation by a predetermined correction coefficient can be taken as the correction error in the misregistration correction using a latent image mark, and the calculation of the cumulative correction error can be simplified. Furthermore, although the temperature in the image forming apparatus is estimated and the misregistration amount is estimated based on the estimated temperature in the misregistration correction through estimation, the configuration may be such that the temperature in the image forming apparatus is actually measured and the misregistration amount is estimated based on the measured temperature.

Second Embodiment

Hereinafter, a second embodiment will be described, focusing on the differences from the first embodiment. The present embodiment differs from the first embodiment in that correction that takes into consideration expansion/constriction of the intermediate transfer belt **30** is added when performing misregistration correction using a latent image mark.

In the present embodiment, to detect variations in the movement velocity of the surface of the intermediate transfer belt **30**, a plurality of belt velocity detection marks **38** are provided at equal intervals at one end of the surface of the intermediate transfer belt **30**, as shown in FIG. **5**B, and the detection sensor **37** detects the belt velocity detection marks **38**. The control unit **54** calculates the movement velocity of the surface of the intermediate transfer belt **30** (hereinafter referred to as "belt velocity") from the time interval between the belt velocity detection marks **38** detected by the detection sensor **37** while driving the intermediate transfer belt **30**.

FIG. **11**A is a flowchart illustrating a reference value obtainment process according to the present embodiment. In the present embodiment, a reference velocity, which is an average belt velocity value, is obtained in addition to the reference value described in the first embodiment. In S**70**, the control unit **54** executes the process illustrated in FIG. **4**. Doing so results in a minimum amount of misregistration. Then, in S**71**, the control unit **54** performs preparatory operations for forming the latent image mark, and in S**72**, forms one or more latent image marks on the photosensitive member **22** and starts detecting the belt velocity. In S**73**, the control unit **54** detects the latent image mark based on the charging current. In S**74**, the control unit **54** saves the amount of time until the latent image mark **80** formed in S**72** is detected in S**73** as the reference value. Note that in the case where a plurality of latent image marks **80** are formed, an average value of the times until each latent image mark **80** that has been formed is detected is saved as the reference value. Furthermore, in S**74**, the control unit **54** saves the average belt velocity value whose measurement was started in S**72** as a reference velocity.

Next, misregistration correction using the reference value and the reference velocity obtained through the process illustrated in FIG. **11**A will be described using FIG. **11**B. In S**80**, the control unit **54** executes the processes of S**71** to S**73** of FIG. **11**A, and measures the amount of time from the formation to detection of the latent image mark **80**, for each photosensitive member **22**. The belt velocity is also detected. In S**81**, the control unit **54** calculates a misregistration amount I, which is a difference between the measured time and the reference value. Next, in S**82**, the control unit **54** calculates a percentage N (%) of the average belt velocity value measured in S**80** relative to the reference velocity through the following formula.

$$N=(Sp/\mathrm{Ref}S)\times 100$$

Note that Sp represents the average belt velocity value measured in S**80**, and RefS represents the reference velocity. In S**83**, the control unit **54** determines a misregistration amount L based on the percentage N. Note that the determination of the misregistration amount L uses, for example, a table indicating relationships between percentages N and misregistration amounts for each color set in advance for the image forming apparatus, as shown in FIG. **9**B. Note that the table shown in FIG. **9**B indicates misregistration amounts in terms of numbers of lines.

In S**84**, the control unit **54** takes the total of the misregistration amount I obtained in S**81** and the misregistration amount L obtained in S**83** as a total misregistration amount K to be corrected, and carries out a correction process. In the present embodiment, variations in the belt velocity caused by the expansion/constriction of the intermediate transfer belt **30** is taken into consideration, and thus error in the misregistration correction using a latent image mark can be suppressed.

Note that in the present embodiment, the second cumulative correction error is calculated by integrating a value multiplied by a correction coefficient M with a difference between a correction amount H in the misregistration correction through estimation and the correction amount K in the misregistration correction using a latent image mark (that is, the value obtained in S**84** of FIG. **11**B). Note also that the correction coefficient M is a coefficient for reducing the cumulative correction error, and can be a coefficient less than 1. For example, taking into consideration the precision of the misregistration correction that employs the percentage N of the velocity variation, a correction coefficient M of 0.9 can be used.

Other Embodiments

Embodiments of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions recorded on a storage medium (e.g., non-transitory computer-readable storage medium) to perform the functions of one or more of the above-described embodiments of the present invention, and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiments. The computer may comprise one or more of a central processing unit (CPU), micro processing unit (MPU), or other circuitry, and may include a network of separate computers or separate computer processors. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2013-120107, filed on Jun. 6, 2013, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An image forming apparatus comprising:

an image forming unit configured to form developer images of a plurality of colors on an image carrier; and

a control unit configured to execute a first correction control and a second correction control that has a higher correction precision than the first correction control in order to correct misregistration between the developer images formed by the image forming unit,

wherein the control unit is further configured to determine a correction error of the first correction control when executing the first correction control, to determine a cumulative correction error, which is a cumulative value of the correction error of the first correction control, and to execute the second correction control when the cumulative correction error of the first correction control exceeds a first threshold.

2. The image forming apparatus according to claim **1**,

wherein the control unit is further configured to set the cumulative correction error of the first correction control to an initial value when executing the second correction control.

3. The image forming apparatus according to claim **1**,

wherein the first correction control is correction control carried out based on a measurement or an estimation of a temperature in the image forming apparatus, and the second correction control is correction control carried out based on detection of an electrostatic latent image formed on a photosensitive member.

4. The image forming apparatus according to claim 1, wherein the first correction control is correction control carried out based on a measurement or an estimation of a temperature in the image forming apparatus, and the second correction control is correction control carried out based on detection of a developer image formed on the image carrier by the image forming unit.

5. The image forming apparatus according to claim 3, wherein the cumulative correction error of the first correction control is determined based on a measured temperature or an estimated temperature in the image forming apparatus.

6. The image forming apparatus according to claim 1, wherein the image forming unit includes a photosensitive member on which an electrostatic latent image is formed and is further configured to form the developer image on the image carrier by developing the electrostatic latent image formed on the photosensitive member using a developer and transferring the developer image onto the image carrier; and

the first correction control is correction control carried out based on detection of the electrostatic latent image formed on the photosensitive member of the image forming unit, and the second correction control is correction control carried out based on detection of the developer image formed on the image carrier by the image forming unit.

7. The image forming apparatus according to claim 1, wherein the control unit is further configured to execute a third correction control that has a higher correction precision than the second correction control when a cumulative correction error of the second correction control, which is a cumulative value of a correction error occurring when performing misregistration correction using the second correction control, exceeds a second threshold.

8. The image forming apparatus according to claim 7, wherein the control unit is further configured to set the cumulative correction errors of the first correction control and the second correction control to respective initial values when executing the third correction control.

9. The image forming apparatus according to claim 7, wherein the image forming unit includes a photosensitive member on which an electrostatic latent image is formed and is further configured to form the developer image on the image carrier by developing the electrostatic latent image formed on the photosensitive member using a developer and transferring the developer image onto the image carrier; and

the first correction control is correction control carried out based on a measurement or an estimation of a temperature in the image forming apparatus, the second correction control is correction control carried out based on detection of an electrostatic latent image formed on the photosensitive member of the image forming unit, and the third correction control is correction control carried out based on detection of the developer image formed on the image carrier by the image forming unit.

10. The image forming apparatus according to claim 9, wherein the control unit is further configured to detect a movement velocity of a surface of the image carrier, and in the second correction control, a misregistration amount to be corrected is determined based on a misregistration amount obtained by detecting the electrostatic latent image and a misregistration amount caused by variations in the movement velocity of the surface of the image carrier.

11. The image forming apparatus according to claim 9, wherein the cumulative correction error of the first correction control is determined based on the measured temperature or the estimated temperature in the image forming apparatus.

12. The image forming apparatus according to claim 9, wherein the cumulative correction error of the second correction control is determined from a value based on a difference between the misregistration amount in the second correction control and a misregistration amount in the case where the first correction control is executed.

13. The image forming apparatus according to claim 9, wherein the cumulative correction error of the second correction control is determined by multiplying the cumulative correction error of the first correction control by a predetermined coefficient.

14. An image forming apparatus comprising:

an image forming unit configured to form developer images of a plurality of colors on an image carrier; and

a control unit configured to execute a first correction control and a second correction control that has a higher correction precision than the first correction control in order to correct misregistration between the developer images formed by the image forming unit,

wherein the control unit is further configured to execute the first correction control more frequently than the second correction control regardless of a number of execution times of the second correction control.

15. The image forming apparatus according to claim 14, wherein the control unit is further configured to execute the first correction control more frequently than the second correction control by executing the second correction control and setting a cumulative correction error of the first correction control, which is a cumulative value of correction error occurring when performing misregistration correction using the first correction control, to an initial value when the cumulative correction error of the first correction control exceeds a first threshold.

16. An image forming apparatus comprising:

an image forming unit configured to form developer images of a plurality of colors on an image carrier; and

a control unit configured to execute a first correction control, a second correction control that has a higher correction precision than the first correction control, and a third correction control that has a higher correction precision than the second correction control, in order to correct misregistration between the developer images formed by the image forming unit,

wherein the control unit is further configured to execute the first correction control more frequently than the second correction control and execute the second correction control more frequently than the third correction control.

17. The image forming apparatus according to claim 16, wherein the control unit is further configured to execute the first correction control more frequently than the second correction control and execute the second correction control more frequently than the third correction control by executing the second correction control and setting a cumulative correction error of the first correction control, which is a cumulative value of correction error occurring when performing misregistration correction using the first correction control, to an initial value when the cumulative correction error of the first correction control exceeds a first threshold and by executing the third correction control and setting the cumulative correction error of the first correction control and a cumu-

lative correction error of the second correction control, which is a cumulative value of correction error occurring when performing misregistration correction using the second correction control, to respective initial values when the cumulative correction error of the second correction control exceeds a second threshold.

18. The image forming apparatus according to claim **14**, wherein the first correction control is carried out based on a measurement or an estimation of a temperature in the image forming apparatus, and the second correction control is carried out based on detection of an electrostatic latent image formed on a photosensitive member.

19. The image forming apparatus according to claim **14**, wherein the first correction control is carried out based on a measurement or an estimation of a temperature in the image forming apparatus, and the second correction control is carried out based on detection of a developer image formed on the image carrier by the image forming unit.

20. The image forming apparatus according to claim **14**, wherein the image forming unit includes a photosensitive member on which an electrostatic latent image is formed and is further configured to form the developer image on the image carrier by developing the electrostatic latent image formed on the photosensitive member using a developer and transferring the developer image onto the image carrier; and

the first correction control is carried out based on detection of the electrostatic latent image formed on the photosensitive member of the image forming unit, and the second correction control is carried out based on detection of the developer image formed on the image carrier by the image forming unit.

21. The image forming apparatus according to claim **16**, wherein the image forming unit includes a photosensitive member on which an electrostatic latent image is formed and is further configured to form the developer image on the image carrier by developing the electrostatic latent image formed on the photosensitive member using a developer and transferring the developer image onto the image carrier; and

the first correction control is carried out based on a measurement or an estimation of a temperature in the image forming apparatus, the second correction control is carried out based on detection of an electrostatic latent image formed on the photosensitive member of the image forming unit, and the third correction control is carried out based on detection of the developer image formed on the image carrier by the image forming unit.

22. An image forming apparatus comprising:

an image forming unit configured to form developer images of a plurality of colors on an image carrier; and

a control unit configured to execute a first correction control for correcting misregistration in the developer images formed by the image forming unit, to determine a correction error of the first correction control when executing the first correction control, to determine a cumulative correction error, which is a cumulative value of the correction error of the first correction control, and to control, based on the cumulative correction error of the first correction control, a timing at which a second correction control, which is different than the first correction control and is for correcting misregistration in the developer images formed by the image forming unit, is executed.

* * * * *